An Innovative Activated Sludge System for Enhanced Nutrient Recovery via Downstream Cultivation of Green Microalgae

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An Innovative Activated Sludge System for Enhanced Nutrient Recovery via Downstream Cultivation of Green Microalgae

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1. INTRODUCTION

Current resource recovery strategies [1]:

- Metal salt addition for phosphorus precipitation
- Ammonia stripping and recovery as salt
- Ultrafiltration
- Reverse osmosis

Disadvantages:
- High energy demand
- Requires metal salts

Resource recovery through a two-stages bacterial-algal system [2]:

- Enhanced biological phosphorus removal and recovery system (EBP2R) to produce growth media with targeted N-to-P ratios
- Optimal algal cultivation, thereby intracellularly storing both N and P
- Direct application on land for fertigation

Advantages:
- Complete biological process
- Comparably lower environmental impact

Optimal N-to-P ratio

Fertigation

2. OBJECTIVES

The goals of this study are to

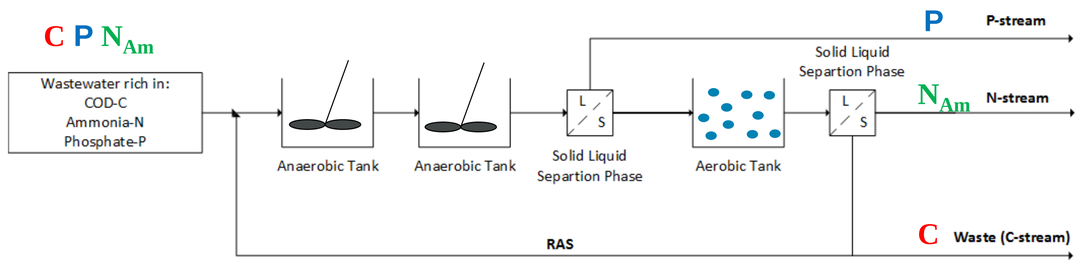
i) provide the **model-based design** of the EBP2R system

ii) **optimize** the nutrient recovery capacity

iii) analyse the sensitivity of the nutrient recovery performance with regard to the influent fractionation and biological processes through **global sensitivity analysis** (GSA)

3. METHODS

- System description:



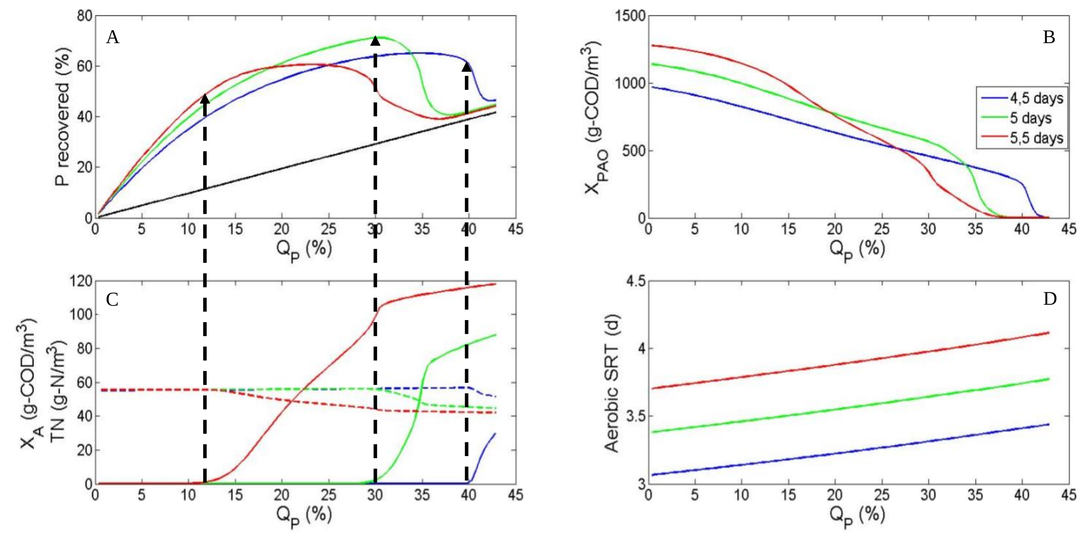
- P-stream: phosphorus rich stream diverted form the anaerobic tanks
- N-stream: ammonia rich stream obtained by keeping a comparably low aerobic SRT
- C-stream: wastage of the sludge to the anaerobic digester

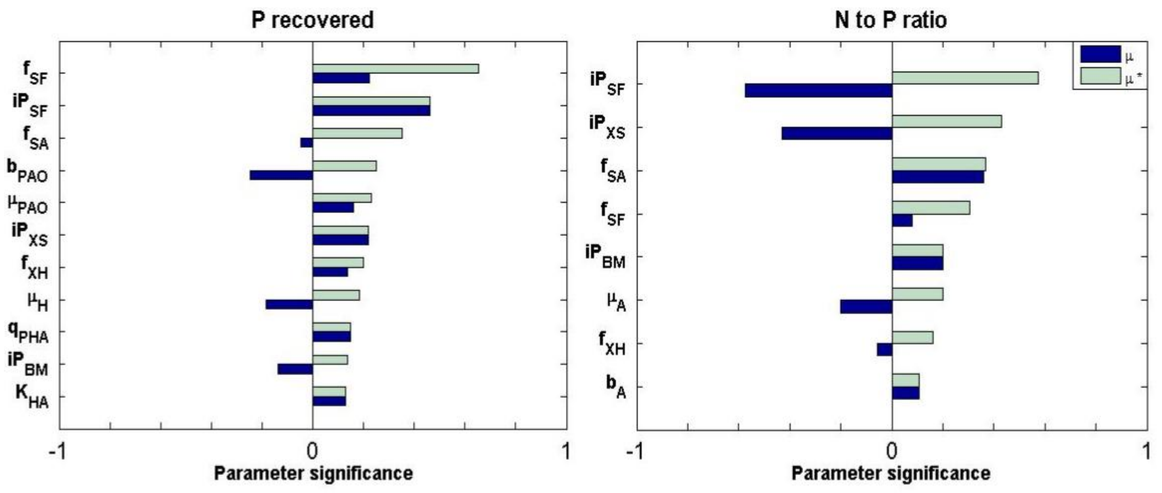
- System is modeled using the activated sludge model 2d (ASM-2d) [3]

- GSA: Morris screening [4]
  - Estimates the distribution of the elementary effects (*EE*) of each input parameter to the model output
  - Ranking is established based on the mean of the absolute values of *EE* (μ^*)

Sampling parameter space → Simulation of the EBP2R using sampled parameters → Calculation of the sensitivity measures

4. RESULTS



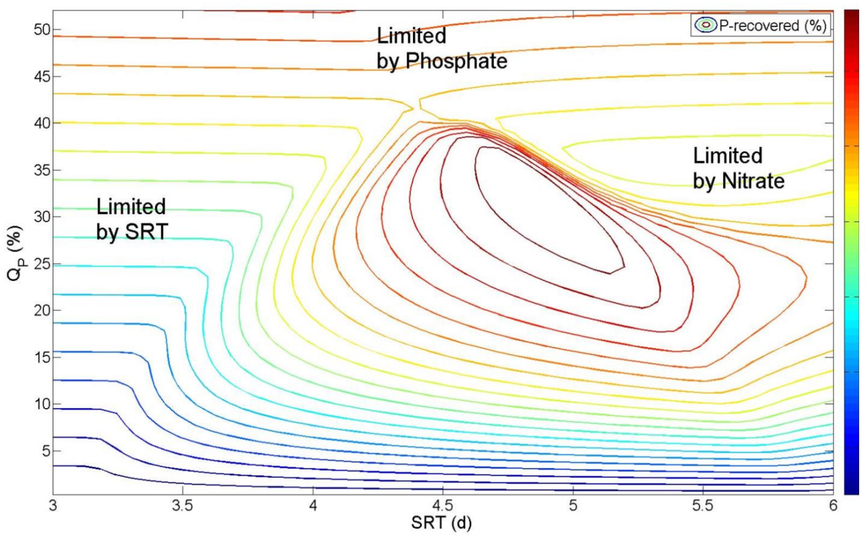


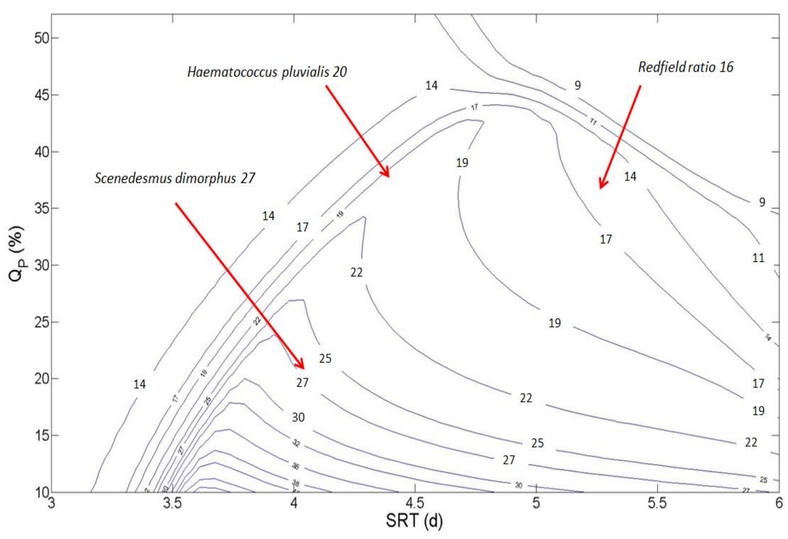
Exploring the system behavior:

A. Increase in P-recovery up to a maximum load as function of the Qp
B. Maximum P-recovery corresponds to the onset of PAOs wash-out
C. PAOs are washed-out due to the nitrifier activity
D. Nitrifiers grow at high P-stream flows because the aerobic SRT increases due to solids up-concentration in the aerobic reactor

Global sensitivity analysis:

- P-recovery is mainly dependent on the influent wastewater fractions:
  - Effect of the COD fractions depends on fate in the system (growth vs storage) and the associated nutrient content (iPSF and iPxs)
- N-to-P ratio mainly dependent on the influent fractionations, as consequence of the effect on the P-recovery
- Nitrifiers only affect the N-to-P ratio by removing nitrogen. Bioavailable COD is sufficient to mitigate the nitrate impact on PAO activity





Process optimization:

- Optimal P-recovery at SRT=5 days and Qp=0.3·Qin. At other conditions PAO activity is limited by:
  - SRT
  - Phosphate starvation in the aerobic reactor
  - Nitrate recirculation to the anaerobic reactors
- The EBP2R is able to yield to N-to-P ratios optimal for cultivation of different green-microalgae :
  - *Scenedesmus dimorphus* N/P=27
  - *Haematococcus pluvialis* N/P=20
  - *Redfield ratio* N/P=16
- Algae chosen to grow in the PhBR have to be able to take up all the incoming phosphorus and nitrogen at high P-recovery rates

5. CONCLUSIONS

- Phosphorus recovery by the **EBP2R is controlled by 3 different factors**: system SRT, phosphorus availability in the aerobic reactor and nitrate recycling to the anaerobic tanks. The **optimal operation conditions** through scenario simulations are an **SRT of 5 days and Q_P of 0.3·Qin**. This results in **70% of the influent P recovered**.
- The EBP2R can be used to construct different N-to-P effluent ratios. Using a typical municipal influent wastewater, the constructed **effluent quality can be optimized in terms of nutrient balance for different green micro-algae,** such as *Scenedesmus dimorphus* or *Haematococcus pluvialis*.
- GSA show that after optimization of the EBP2R, the variability of the **P recovery and the effluent N-to-P ratio** in the EBP2R **primarily depends on the influent wastewater quality** rather than on the kinetics or stoichiometry of the biological processes in the EBP2R system.

References:

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